Gondwana Research 38 (2016) 74–85

Contents lists available at ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

Middle Permian U–Pb zircon ages of the "glacial" deposits of the Atkan Formation, Ayan-Yuryakh anticlinorium, Magadan province, NE Russia: Their significance for global climatic interpretations

V.I. Davydov [a,b,*], A.S. Biakov [b,c], J.L. Isbell [d], J.L. Crowley [a], M.D. Schmitz [a], I.L. Vedernikov [c]

[a] Department of Geosciences, Boise State University, Boise, ID 83725, USA
[b] Kazan Federal University, 18 Kremlyovskaya St., Kazan, Republic of Tatarstan 420008, Russia
[c] North-East Interdisciplinary Scientific Research Institute N.A. Shilo, Far East Branch of the Russian Academy of Sciences, 16 Portovaya, St., Magadan 685000, Russia
[d] Department of Geosciences, University of Wisconsin—Milwaukee, Milwaukee, WI 53201, USA

ARTICLE INFO

Article history:
Received 23 April 2015
Received in revised form 11 October 2015
Accepted 17 October 2015
Available online 19 November 2015

Handling Editor: R. Goldfarb

Keywords:
Guadalupian volcanism
Middle–Late Permian glaciation
U/Pb geochronology
Guadalupian climate
North-East Russia

ABSTRACT

The Atkan Formation in the Ayan-Yuryakh anticlinorium, Magadan province, northeastern Russia, is of great interest because of the occurrence of deposits of apparent "dropstones" and "ice rafted debris" that have been previously interpreted as glacial. Two high-precision U–Pb zircon ages, one for an intercalated volcanic tuff (262.5 ± 0.2 Ma) and the other for a boulder clast (269.8 ± 0.1 Ma) within a diamictite of the Atkan Formation, constrain the age of the Atkan Formation as Guadalupian (middle Permian). Sedimentologic study of the Atkan Formation casts doubt on the glacial nature of the diamictites. Deposition of rocks of the Atkan Formation temporally correlates with the Capitanian interglacial event in the southern hemisphere that recently was calibrated with high precision CA-TIMS. The previously proposed climate proxy record based upon warm-water foraminifera, which corresponds closely to global climate fluctuations, is compared with the glacial record of eastern Australia and indicates that the Capitanian was a time of globally warm climate. The sedimentology of Atkan Formation, the record of diversification of both fusulinids and rugosa corals, global sea-water temperature, and sea-level fluctuations agree well with high latitude paleoclimate records in northeastern Russia and eastern Australia. Major components of the Atkan Formation, the volcanic rocks, are syngenetic with the sedimentation process. The volcanic activity in the nearby regions during middle–late Permian was quite extensive.
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1. Introduction

Bipolar ice caps are a main feature of many models for Earth's glaciations. For the late Paleozoic ice age, the evidence for bipolarity is not so obvious, although it is assumed in most publications (i.e., González and Díaz Saravia, 2010; Montanez and Poulsen, 2013 and references there within). The Permian in northeastern Russia contains key sedimentary deposits that have been previously interpreted as glacial. The most cited glacial unit is the upper Permian Atkan Formation in Magadan province, northeastern Russia, and correlative units in the Omolon microcontinental block (Epshteyn, 1972; Chumakov, 1994; Raymond et al., 2004; Chumakov, 2015), where glacial deposits, including dropstones and ice rafted debris were reported (e.g., Epshteyn, 1972; Chumakov, 1994). These upper Permian deposits (in the older sense, but which now include middle [Guadalupian] and upper [Lopingian] Permian of the recent geologic time scale) have become the most commonly cited evidence for late Paleozoic glaciation in the Northern Hemisphere (Chumakov, 1994; Isbell et al., 2012; Montanez and Poulsen, 2013). Other Pennsylvanian and Cisuralian glacial deposits in northeastern Asia are very poorly documented or constrained (Ustritskiy and Yavshits, 1971).

Permian chronostratigraphy in northeastern Russia and correlative units outside of the region are still poorly defined due to an absence of diverse and high resolution conodont or fusulinid fossil faunas; the strong provinciality within other fossil faunas including brachiopods, bivalves, smaller foraminifera, and ammonoids; and a lack of radiometric dates. Although recent biostratigraphic studies have greatly improved the chronostratigraphy of these strata (Ganelin and Biakov, 2006; Klets et al., 2006; Kutygin, 2006; Karavaeva and Nestell, 2007; Biakov, 2010; Davydov and Biakov, in press), many problems remain in constraining the important paleobiologic and geologic events in this region. The presence of Permian volcanism is currently disputed by some geologists, and volcanic material, including boulders and gravel within the Atkan Formation, is interpreted as Devonian in age (Epshteyn, 1981; Chumakov, 1994; Ganelin, 1997, 2013). The new interpretations of the Atkan Formation as volcanoclastic diamictites (Biakov et al.,

* Corresponding author at: Department of Geosciences, Boise State University, Boise, ID 83725, USA. Tel.: +1 208 4261119.
E-mail addresses: vdavydov@boisesate.edu (V.I. Davydov), abiakov@mail.ru (A.S. Biakov), jisbell@uwm.edu (J.L. Isbell), JimCrowley@boisestate.edu (J.L. Crowley), MarkSchmitz@boisestate.edu (M.D. Schmitz), ivedernikov@rambler.ru (I.L. Vedernikov).

http://dx.doi.org/10.1016/j.gr.2015.10.014
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